

# SPHERES

Synchronized, Position, Hold, Engage, Reorient,  
Experimental Satellites



## SPHERES/Astrobee Working Group (SAWG) Quarterly Meeting

Feb 28th, 2018





# Agenda

SPHERES/Astrobee Working Group		Join by phone 1-844-467-4685; 226968			
Date: Feb. 27th, 2018, 11pm PST		Virtual			
Agenda	Group	Project	Name	Time	duration (min)
A	NASA Ames	SPHERES/Astrobee Facility	Jose Benavides	11:00 PM	0:15
B	JAXA	Int-Ball	Wada Masaru	11:15 PM	0:15
C	AIRBUS/DLR	CIMON	Christian Karrasch	11:30 PM	0:15
	Followon Discussion			11:45 PM	0:15
Date: Feb. 28th, 2018, 9am PST		Virtual			
Agenda	Group	Project	Name	Time	duration (min)
1	NASA Ames	SPHERES/Astrobee Facility	Jose Benavides	9:00 AM	0:20
2	Stanford	Gecko-Inspired Adhesive Appendages for Autom	Marco Pavone	9:20 AM	0:10
3	MIT	SPHERES SmoothNav, ReSWARM, Zero Robotics	Alvar/Danilo/Katie	9:30 AM	0:10
4	FIT	RINGS/SVGS	Hector	9:40 AM	0:10
5	NASA Logistics	REALM-2	Andres Chu	9:50 AM	0:10
6	University of Lisbon, Portugal		Rodrigo Ventura	10:00 AM	0:10
7	Airbus	Tether-Slosh	Hans	10:10 AM	0:10
8	Naval Postgraduate School	Propellantless mobility for spacecraft	Marcello Romano	10:20 AM	0:10



# SPHERES Community

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## ❑ SPHERES Working Group (SWG) Quarterly meeting

- Membership includes MIT, FIT, AFS, DARPA, CASIS, Airbus, and NASA (HQ, KSC, JSC, MSFC, and ARC)
- Face-to-Face, twice a year
- Next will be scheduled in May 2018, location TBD

## ❑ Purpose:

- Information sharing across the SPHERES/Astrobee community
  - Astrobee Facility shares
    - ✓ National Lab Facility availability
    - ✓ Status of resources (batteries, CO2 tanks, etc.),
    - ✓ Overall Calendar (scheduled Test Sessions, upmass/return), and
    - ✓ Updates on “new” PD, Investigations, and ISS infrastructure.
  - Provide the SPHERES/Astrobee community (PD, investigators, etc.) with up-to-date information to determine opportunities to use the NL Facility
  - Discuss proposed changes/updates to Astrobee Nat Lab which may be required to support a specific activity or research.
  - Discuss specific support requests made to the ISS Office
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# Today's Goals

□ The SPHERES/Astrobee Facility success as a platform for technology development and fundamental research depends on the success of it's users

- What's your current goal with Astrobee? (Lab Demo? ISS Demo?)
- Plan for getting there
- Are there some make-sense partnerships with other groups here?







# Goals (Free Flyer Community)

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☐ **Sharing of information and lessons learned**

☐ **Explore opportunities in Interoperability**

- Reference: “CCSDS Report Concerning Space Data System Standards, Telerobotic Operations”
- <https://public.ccsds.org>



# First exchange/collaboration meeting between Astrobees and Int-Ball teams

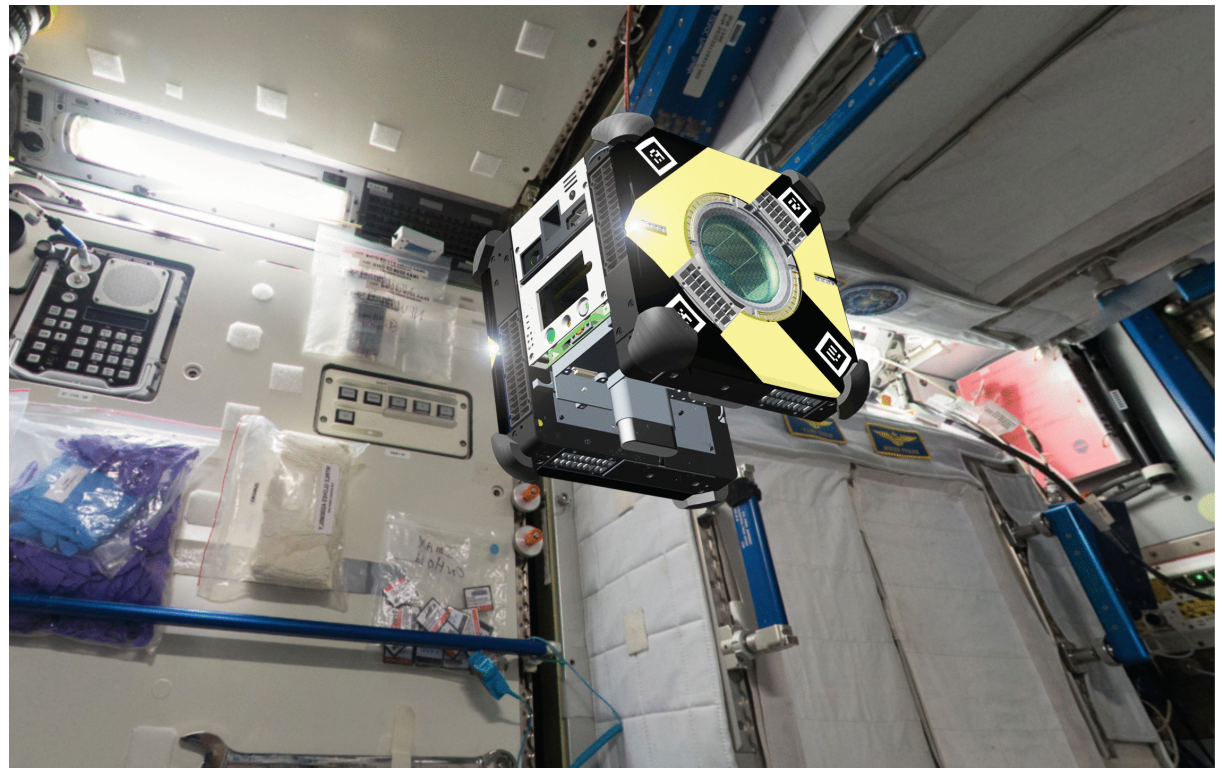
- ❑ **Multiple meetings held in Japan in January, 2018**
- ❑ **Int-Ball – Astrobees meeting**
  - Introduction of Astrobees and Int-Ball designs/systems
  - Possible collaboration among teams
- ❑ **JAXA/NASA TIM meeting**
  - Use cases for simultaneous operation of Int-Ball and Astrobees





# What's next ...

- ☐ Next ZR competition is under way
- ☐ Continuing Vertigo Smooth Navigation research
- ☐ Continuing Tether-Slosh
- ☐ New SPHERES-ReSWARM
- ☐ **Continue work transitioning to Astrobee**
  - ☐ Goal: Fully operational in 2019
- ☐ First Astrobee Users
  - ☐ REALM-2
  - ☐ Zero Robotics
  - ☐ Astrobotics/Bosch
- ☐ Astrobee Users in the wings
  - ☐ Stanford
  - ☐ NPS





# Guest Science Program (GSP)

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- ☐ What's available from the Astrobee Facility?
  - ☐ Astrobee Robotics Software Simulation
  - ☐ Ground Hardware: Qty 3 & "Flat-Sats"
  - ☐ Labs: Granite & MGTF
  - ☐ Documentation and Training
  - ☐ Proposal Support
  - ☐ ISS Payload Partner
- ☐ How can I use Astrobee and what does it take?
  - ☐ **Guest Scientist Guide** & Mechanical Payload ICD
  - ☐ New Hardware or "just" Software?
  - ☐ Ground Demonstration or ISS Operation?
- ☐ We want to hear from you!
  - ☐ Approximate Scheduling
- ☐ Information found on website

<https://www.nasa.gov/astrobee>



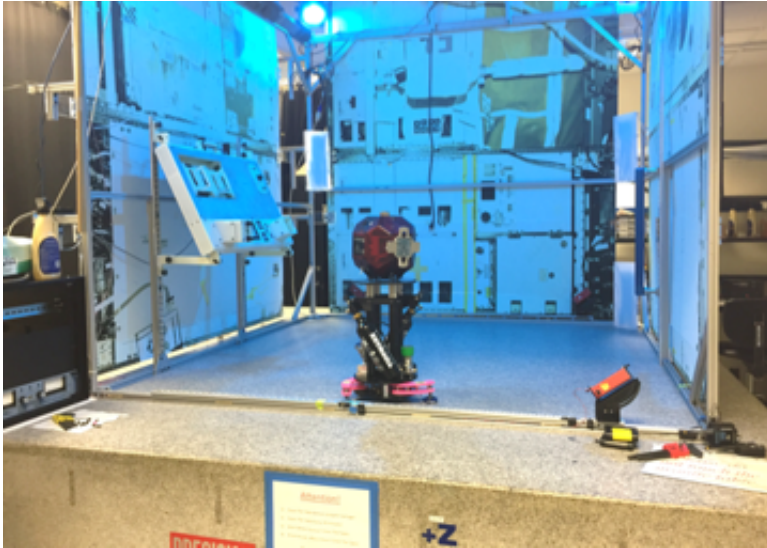


## SPHERES Engineering



# Ground Lab Status

- Granite Lab: Online



- Flight Lab: Online



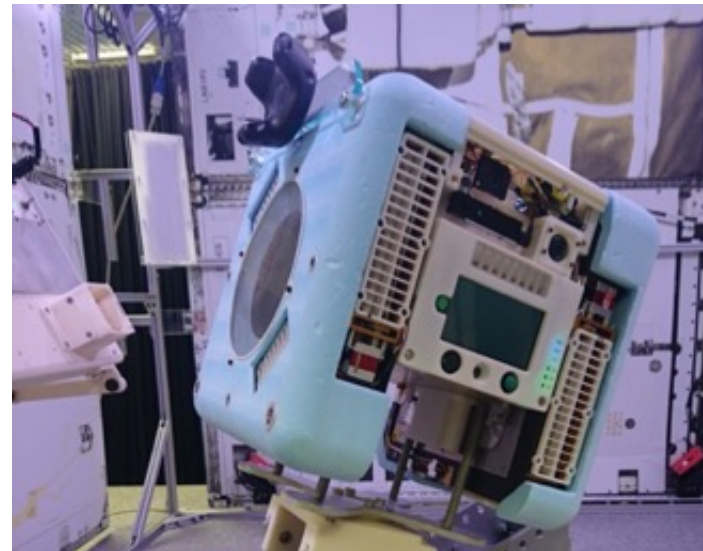
- Micro Gravity Test Facility (MGTF) Lab

- Engineering Evaluation Lab (EEL): Available upon request



# Hardware Fidelity (Astrobee)

Name	Mechanical Fidelity	Electrical Fidelity	Software Fidelity	Sensor Fidelity
P4C	Low	Low	Low	High
P4E	Med	Med-High	High	High
Flat Sat A	Low	High	High	Low/None
Cert	High	High	High	High
Flight 1	High	High	High	High

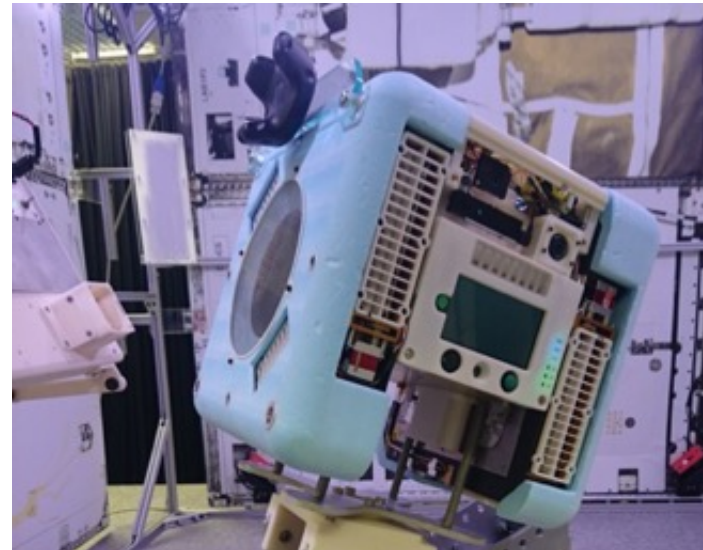






# Hardware Status (Astrobee)

Name	Status	Plans
P4C	End-Of-Life	Available in MGTF but unsupported
P4E	Operational	Dev. Testing in Granite until Cert, then MGTF
Flat Sat A	Operational	JSL testing 03/06, REALM testing during visit
Cert	In-Work	Complete by 04/06, then verification testing
Flight 1	In-Work	Complete by 04/06, then verification testing







# SPHERES & Astrobee Operations



# Increments 53/54 (Sept 2017-Feb 2018)

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## ➤ Increments 53/54 (Sept 2017-Feb 2018)

- |                                     |                   |
|-------------------------------------|-------------------|
| ➤ SmoothNav Science 1               | December 11, 2017 |
| ➤ Zero Robotics High School Dry Run | January 9, 2018   |
| ➤ Zero Robotics High School Finals  | January 11, 2018  |
| ➤ Tether Slosh Science 1            | January 17, 2018  |
| ➤ SmoothNav Science 1 Repeat        | January 30, 2018  |

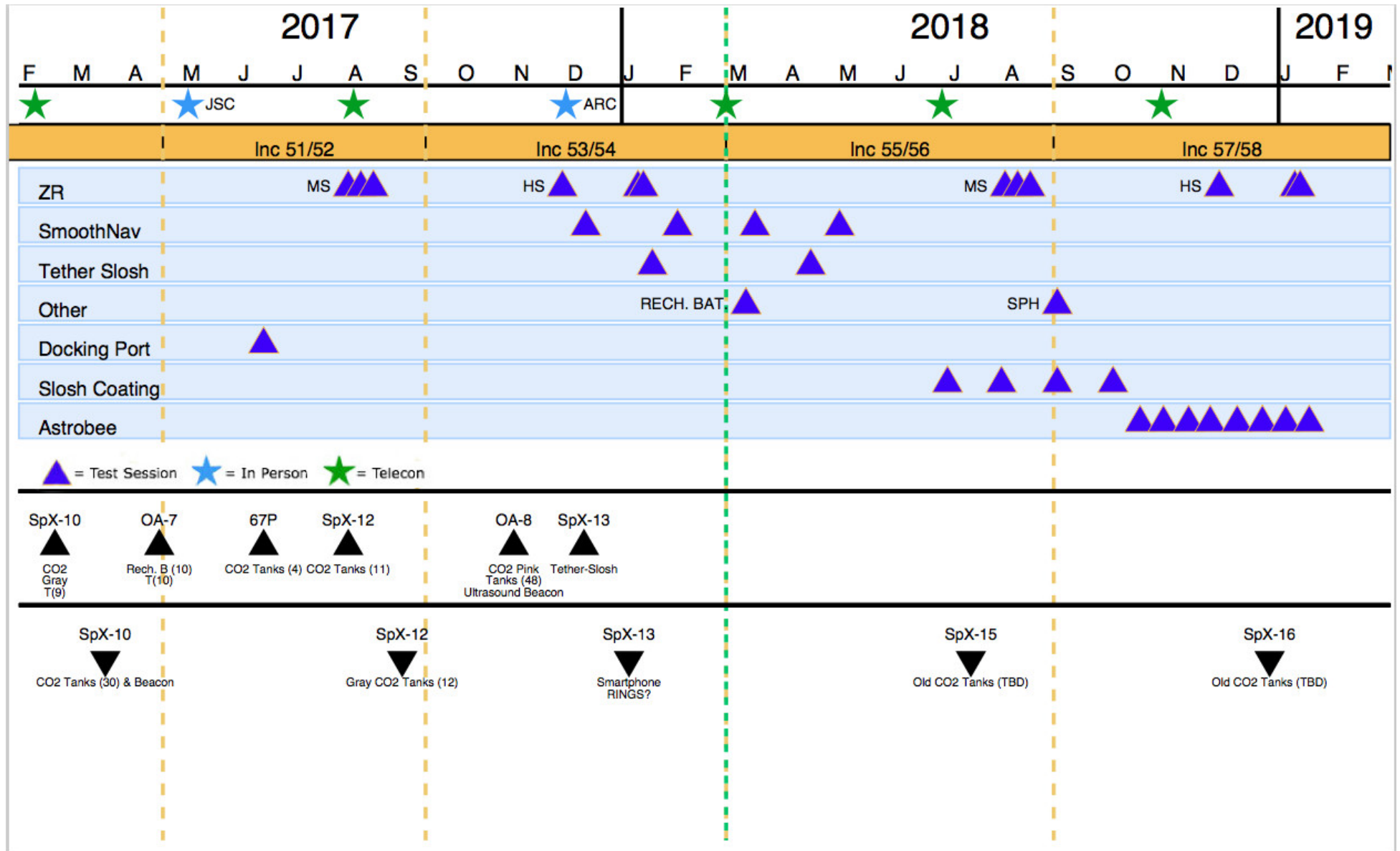
## ➤ Increments 55/56 (Feb 2018 – Aug 2018)

- |                                     |                  |
|-------------------------------------|------------------|
| ➤ SmoothNav Science 2               | March 2018       |
| ➤ Tether Slosh Science 2            | March-April 2018 |
| ➤ SmoothNav Science 3               | ~May 2018        |
| ➤ SmoothNav Science 4               | June-July 2018   |
| ➤ Zero Robotics High School Dry Run | July 2018        |
| ➤ Zero Robotics High School Dry Run | August 2018      |
| ➤ Zero Robotics High School Finals  | August 2018      |

- |  |         |
|--|---------|
| ➤ Additional, <u>Tether Slosh</u> (?), new <u>ReSwarm</u> , <u>Slosh Coating</u> | All TBD |
|--|---------|
-



# SPHERES Calendar





# Consumables Status

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## CO2 Tank Inventory

- **76 Tanks on orbit – should support approximately 23 test sessions**

## Battery Pack Inventory

- **62 Batteries on orbit - should support approximately 9 test sessions**
- 10 SPHERES Rechargeable Batteries arrived on station with OA-7 – procedures approved for testing.





## PIM Update



# PIM Status

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- What integration work has been accomplished since last SPHERES Quarterly Working Group on 11/30/2017?

- **SPHERES Tether Slosh – Flight SpX-13 (12/8/17)**

- January 17<sup>th</sup> – SPHERES Tether Slosh Run #1
- One test session remains (for Inc. 55/56). Additional test sessions to be requested.

- **SmoothNav** – Total of 4 test sessions

- 1<sup>st</sup> test session completed: 12/11/17
- Run #1 –rerun completed: 1/31/18
- 3 test sessions remain

- **RINGS – launched on Flight HTV-4 (08/03/13)**

- RINGS (qty. 2) to potentially return on SpX-14
- 16 DeWalt batteries on the ground will be transitioned over to JSC/Flight Crew Systems (FCS) group. 8 Dewalt batteries remained on-board and will also be transitioned over to FCS group.



# PIM Status--continued

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- **SPHERES Zero Robotics:**

- Inc. 53/54 (09/02/17-02/27/18): completed
  - ZR Unit Test: 11/28/17
  - ZR Dry Run: 01/09/18
  - ZR Competition: 01/11/18

- **Smartphone Hardware- Flight SpX-13 return (1/06/18)**

- HET Smartphone (launched on ULF7) and Smartphone-MM (launched on Orb-2) returned on SpX-13; will be delivered to Ames by end of March 2018

- **SPHERES ReSwarm – on-orbit investigation only**

- CASIS approved – not yet added to IPL

- **SPHERES Consumables - multiple flights**

- Rechargeable batteries –procedures and planning products in work to use these on-orbit.

# ISS Flight Plan (in-work version as of 02/27/18)



For current baseline refer to  
SSP 54100 Multi-Increment  
Planning Document (MIPD)

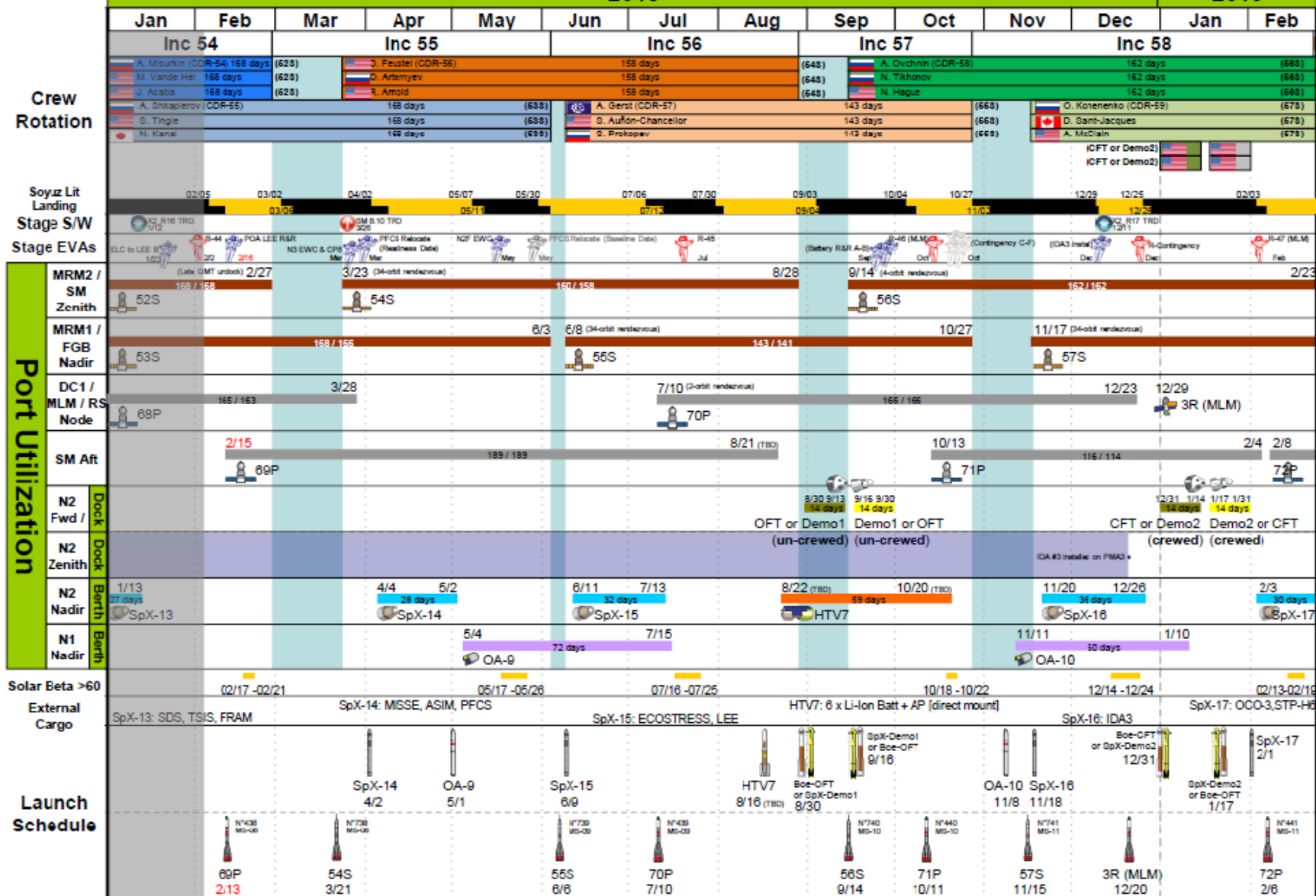
## ISS Flight Plan Flight Planning Integration Panel (FPIP)

NASA: OC4/John Coggeshall  
MAPI: OP/Irene Chan  
Chart Updated: February 15<sup>th</sup>, 2018  
GR: In Work



2018

2019



# Astrobee Update



SPHERES/Astrobee Working Group

February 28, 2018



# Astrobee Team

Oleg Alexandrov

Katie Browne

Maria Bualat

Brian Coltin

Earl Daley

Neil Davies

Lorenzo Fluckiger

Terry Fong

Jesse Fusco

Ryan Goetz

Yunkyung Kim

Dongmeng Li

John Love

Nghia Mai

Mike McIntyre

Don Morr

Ted Morse

Estrellina Pacis

Inwon Park

Greg Paulson

Hugo Sanchez

Trey Smith

Ernie Smith

Corey Snyder

The SPHERES Team

Andrew Symington

Omar Talavera

Vinh To

DW Wheeler

Shang Wu

Jongwoon Yoo

## **Alumni**

Steve Battazzo

Jeff Blair

Jon Dewald

Jeff Feller

Ravi Gogna

Hyunjung Kim

Linda Kobayashi

Brian Koss

Alexandria Langford

Dong-Hyun Lee

Jason Lum

Andy Martinez

Blair Mclachlan

Zack Moratto

Robert Nakamura

Youngwoo Park

Cedric Priscal

Chris Provencher

Jay Torres

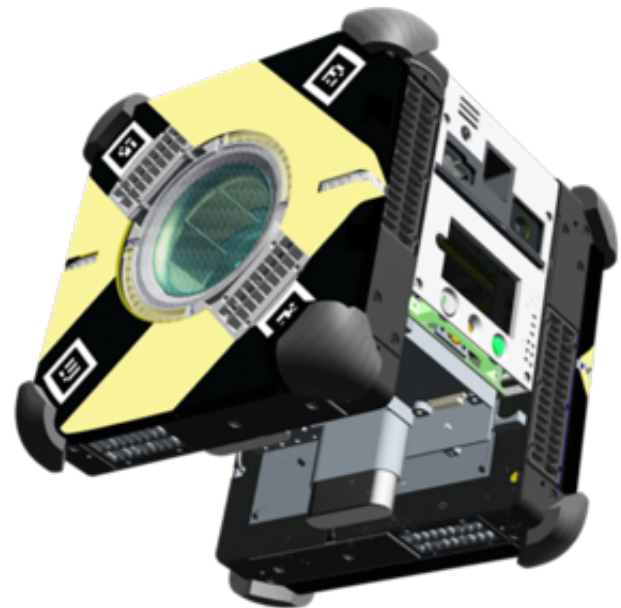
Allison Zuniga





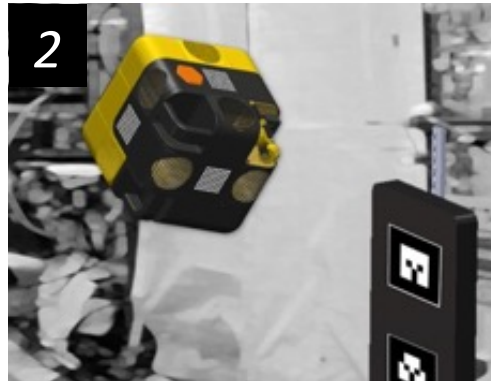
# Astrobee Equipment

- 3 free flyers, dock, spare ORUs on orbit
  - Honey (yellow)
  - Bumble (blue)
  - Queen (green)
- 3 free flyers, 2 docks (1 a flight spare), spares on ground
  - Melissa (pink)
  - B# (purple)
  - Killer (orange)





# Research Scenario



## Sequence of Events

- 1 Prior to research activity, ground operator loads experimental software, free flyer does self-diagnostics.
- 2 Free flyer undocks and moves to experimental module.
- 3 Astronaut attaches external hardware to free flyer.
- 4 Ground operator sets up individual tests, and (optionally) astronaut initializes tests.
- 5 Free flyer perches to wait while astronaut pauses for EPO Event.
- 6 Astronaut detaches hardware and then free flyer returns to dock.



# Contingency Fault Responses

- Unexpected obstacle/crew
  - Stop and wait for instructions
- Low battery
  - Alert and may autonomously return to dock
- LOS
  - Continue nominal operations
  - Long duration WiFi drop: may return to dock
- H/W & S/W failures
  - Halt operations and disable propulsion, articulation and active sensing



# Astrobee Status

- Astrobee hardware delivery has slipped
  - On-dock date August 17, 2018
  - Targeting launch on Orbital-ATK 10 (November 8, 2018)
- Finalizing procurement
- Integration has begun (nozzles and core stack)
- Available to Guest Scientists:
  - Beta release of Flight Software/Simulator (v 0.3 coming soon)
  - Mechanical Payload ICD drawings
  - Initial draft of the Guest Science Guide



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# Astrobee Integration



Y/Z Nozzles



Cert Unit Stack



X Nozzles